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BENDING AND HARDNESS TESTS OF HUMAN RIBS

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Bending tests have been conducted in order to better interpret rib fractures caused by the belt in simulated accidents with fresh cadavers. For this purpose the right 6th and 7th ribs between the anatomical mid-clavicular and posterior axillary line, similar to Granik and Stein, were taken from the test cadaver during the autopsy. Up to now, we have tested 128 rib fragments of 44 male and 20 female individuals who died a natural death, predominantly by cardiac arrest as well as unnatural deaths like poisoning, hanging, drowing, etc.

Approximately 10cm long rib samples were supported over a distance of 8cm and were manually statically loaded in the center by means of a lever arm, whereby the 6th rib was loaded concave and the 7th rib was loaded convex (Figure 1). The bending force was recorded by means of a piezo-electrical force transducer through a charge amplifier at the storage screen of the oscilloscope.

The height and width of the rib was measured on the loaded point with the sliding callipers; furthermore, after the test, did we measure the thickness of the compact bone at the breaking point at four places 90° apart. The Vickers hardness was measured five times adjacent to the fracture point of the 7th rib and the average was established.

Results:

The 64 loaded rib pairs were divided into several age groups. Corresponding averages of the breaking load and the Vickers hardness were registered for each of these age groups.

Figure 2 shows the breaking load - age - dependence of the 6th and 7th rib respectively loaded concave and convex. In the tests with male ribs a maximum was reached between 30 and 40 years which was followed by a decrease of the breaking load with increasing age.

In the female rib tests no maximum was observed due to a lacking of ribs of younger individuals. However, beyond the 20th year of life a decrease of the breaking load with increasing age can be seen as well. The breaking load of female ribs lies underneath the one of male ribs.

In order to relate the measured values of the breaking point to the cross section of the rib, the cross section of the rib was simplified and was equalized to correspond to an ellipse. In the evaluation of the plane only the compact bone was considered, whereas the spongy bone was neglected.

The breaking strength was then normalized by the cross sectional area and plotted as a function of the age (Figure 3). The difference between male and female ribs is extensively reduced as the breaking load is related to the approximate supporting area of the cross section of the rib. The strength decrease with increasing age has been preserved. It can be assumed that enlarged test numbers will eliminate these sex differences to a great extent.

As already mentioned did we measure the Vickers hardness five time adjacent to the fracture point and the average was calculated. Figure 4 shows the dependence of the Vickers hardness on age and sex. In the age of 33 years in both sexes the rib hardness reached a maximum value of 26kp/mm^2 which is then reduced with increasing age.

The fracture pattern of the tested ribs depended on the age but did not depend on the loading direction. Up to the 20th year of life buckling fractures were predominantly observed while in old age mostly transverse fractures occurred. These fracture patterns correspond very well with rib fractures caused in situ by safety belts.

The tests will be continued to ensure a statistically significant statement.

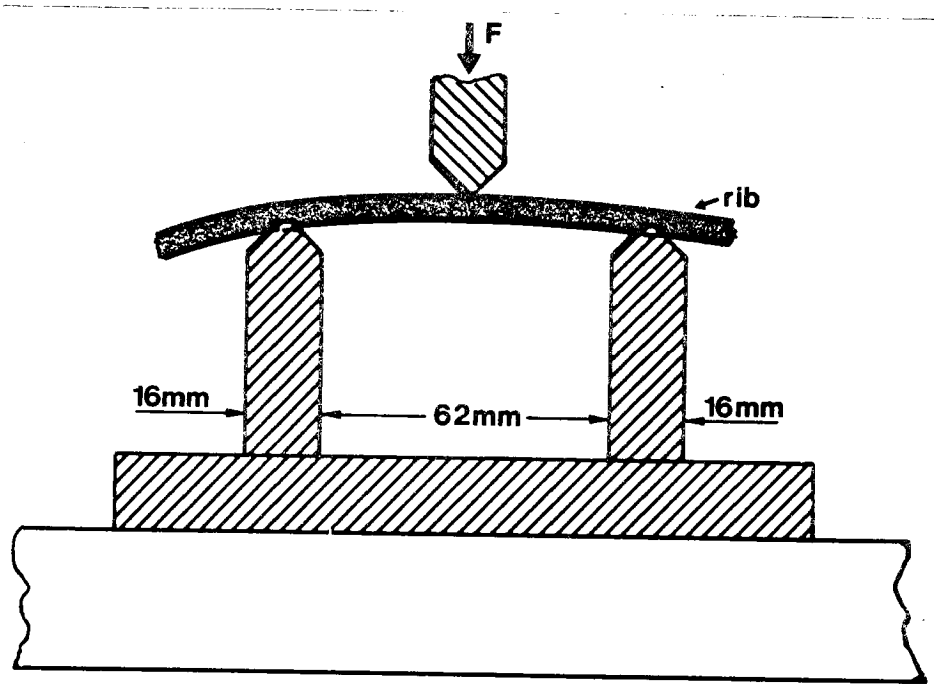

Fig. 1 Rib Bending Test Device

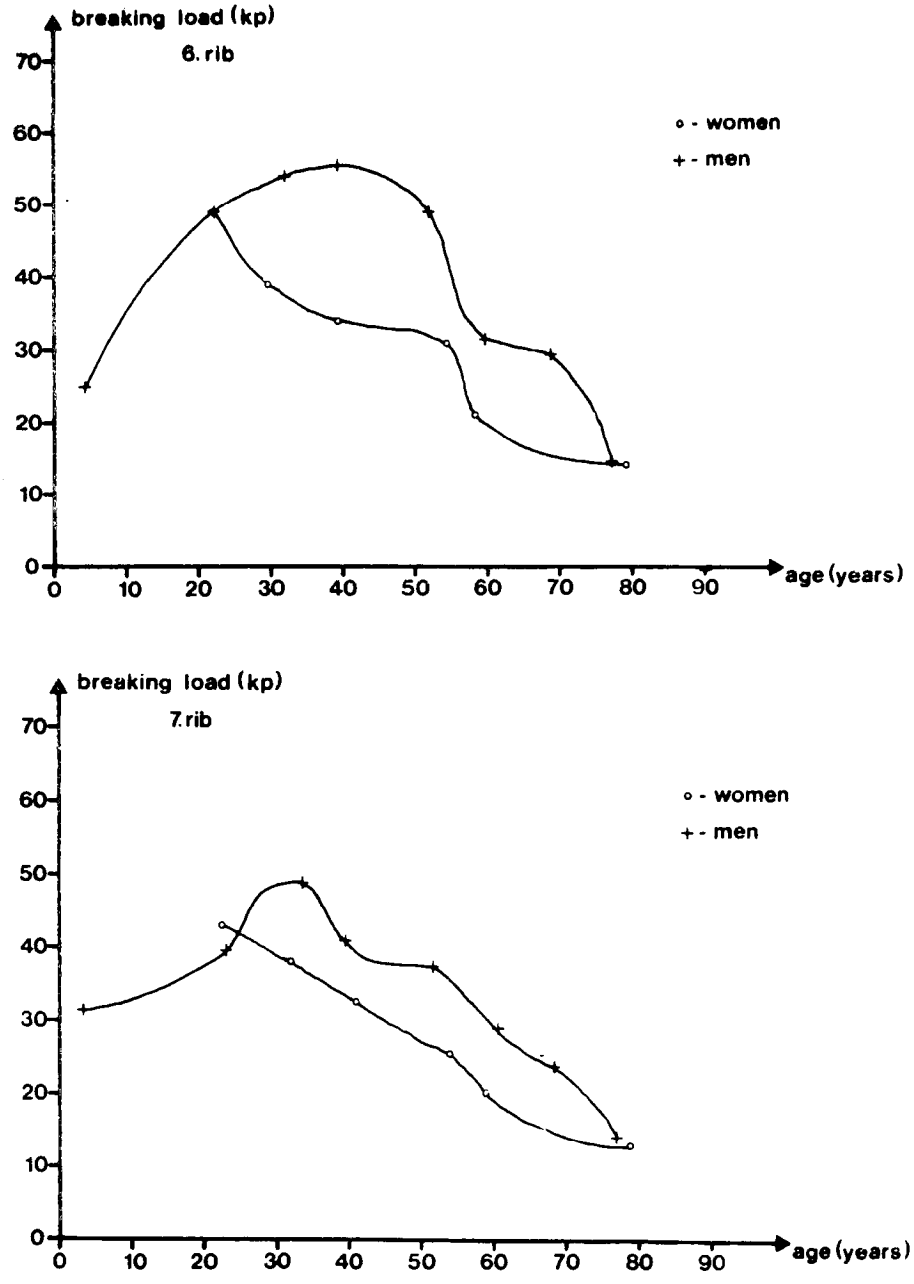

Fig. 2 Breaking Load Dependent on Age of the 6th and 7th Rib

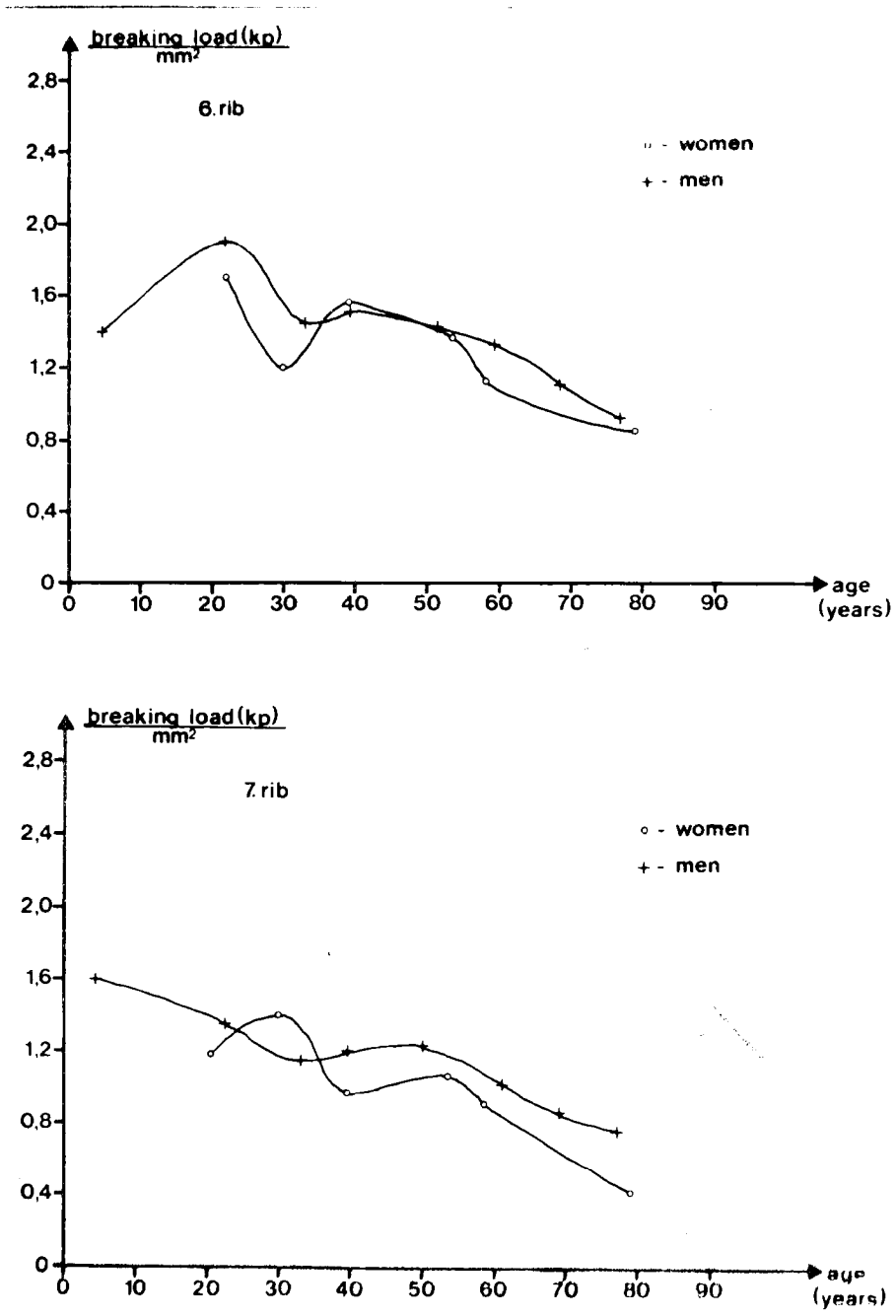

Fig. 3 Breaking Strength Dependent on Age of the 6th and 7th Rib

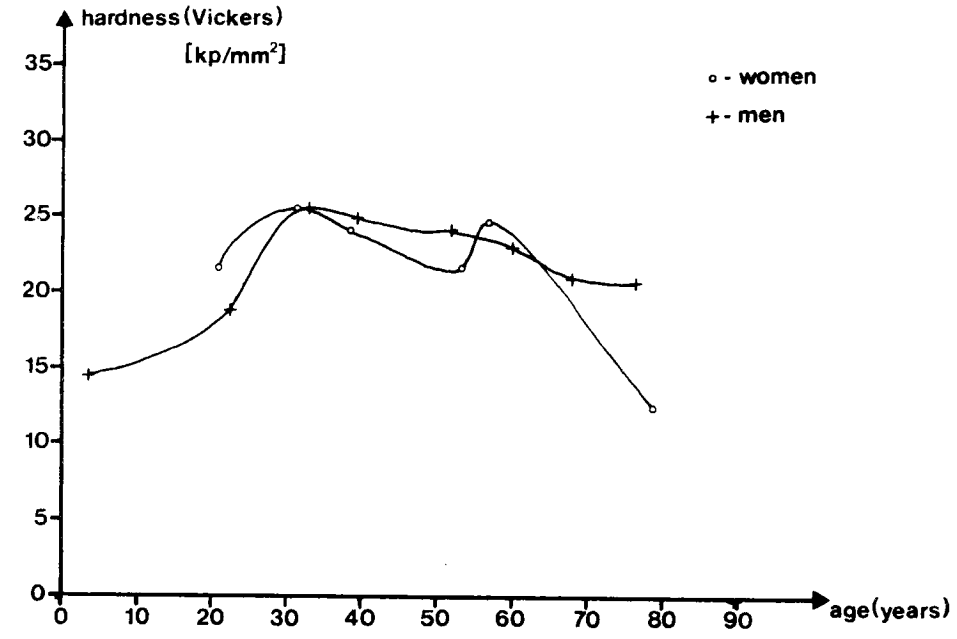

Fig. 4 Rib Hardness in Dependence on the Age